error due to the cause pointed out by the great French chemist, its influence is in the present case inappreciable by existing means of measurement, and no correction of the numbers obtained for the atomic weight in question can be applied which shall have any real meaning.

The other series (1 and 2) of experiments made to determine this atomic weight do not involve the question of gaseous occlusion, at any rate in the same form, as in them the metal itself was not used, but certain of its compounds only.

XIV. On the Spectrum of the Flame of Hydrogen." By WILLIAM HUGGINS, D.C.L., LL.D., F.R.S. Received June 16, 1880.

Messrs. Liveing and Dewar state, in a paper read before the Royal Society on June 10 (*ante* p. 494), that they have obtained a photograph of the ultra-violet part of the spectrum of coal gas burning in oxygen, and in a note dated June 8 they add that they have reason to believe that this remarkable spectrum is not due to any carbon compound but to water.

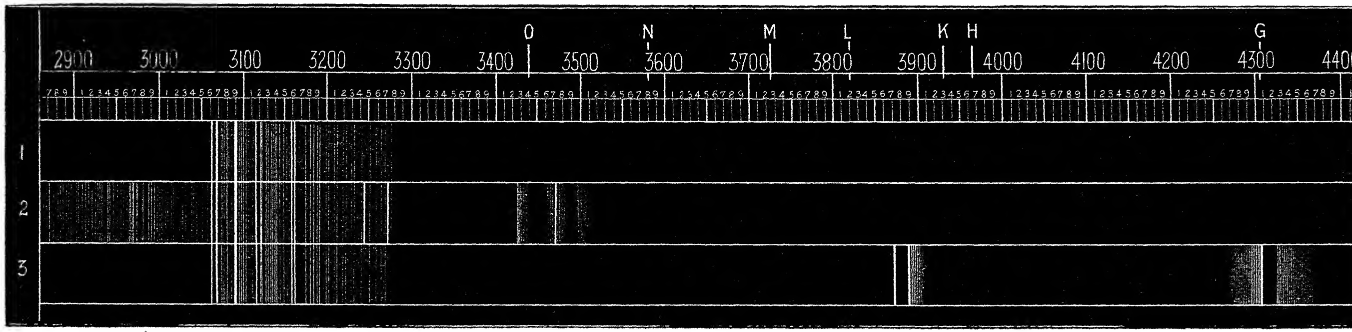
Under these circumstances I think that it is desirable that I should give an account of some experiments which I made on this subject some months since without waiting until the investigation is more complete.

On December 27, 1879, I took a photograph of the flame of hydrogen burning in air. As is well known, the flame of hydrogen possesses but little luminosity, and shows no lines or bands in the visible part of the spectrum, except that due to sodium as an impurity.

Professor Stokes, in his paper "On the Change of Refrangibility of Light,"* had stated that "the flame of hydrogen produces a very strong effect. The invisible rays in which it so much abounds, taken as a whole, appear to be even more refrangible than those which come from the flame of a spirit lamp." I was not, however, prepared for the strong group of lines in the ultra-violet which, after an exposure of one minute and a half, came out upon the plate.

Two or three weeks later, about the middle of January, 1880, I showed this spectrum to Professor Stokes, and we considered it probable that this remarkable group was the spectrum of water. Professor Stokes permits me to mention that, in a letter addressed to me on January 30, he speaks of "this novel and interesting result," and makes some suggestions as to the disputed question of the carbon spectrum.

* "Phil. Trans.," 1852, p. 539.



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I have since that date taken a large number of photographs of the spectra of different flames, in the hope of being able to present the results to the Royal Society, when the research was more complete. I think now that it is desirable that I should describe the spectrum of the flame of hydrogen, but I shall reserve for the present the experiments which relate to the presence of carbon and its compounds.

The spectrum of the flame of hydrogen burning in air is represented in the diagram, Spectrum No. 1. It consists of a group of lines which terminates at the more refrangible limit in a pair of strong lines, λ 3062 and λ 3068. At a short distance, in the less refrangible direction, what may perhaps be regarded as the group proper, commences with a strong line, λ 3090. Between the strong line λ 3068 and the line λ 3090 there is a line less bright, λ 3080. Less refrangible than the line λ 3090 are finer lines at about equal distances. The lines are then fine and near each other, and appear to be arranged in very close pairs. There is a pair of fine, but very distinct lines, λ 3171 and λ 3167. In this photograph the group can be traced to about λ 3290. This group constitutes the whole spectrum, which is due probably to the vapour of water.

I then introduced oxygen into the flame, leaving a small excess of hydrogen. A spectrum in all respects similar came out upon the plate. I repeated the experiment, taking both spectra on the same plate. Through one-half of the slit the spectrum of the oxyhydrogen flame was taken. This flame was about 7 inches long, and the spectrum taken of a part of the flame 2 inches from the jet. The oxygen was then turned off, and the quantity of hydrogen allowed to remain unaltered. A second spectrum with an exposure of the same duration was then taken through the second half of the slit. On the plate the two spectra are in every respect similar, and have so exactly the same intensity, that they appear as one broad spectrum.

In all these experiments a platinum jet which had been carefully cleaned was used.

In these experiments the two gases met within the blowpipe and issued in a mixed state.

The jet was removed, and a flame of hydrogen was surrounded with oxygen. The spectrum, No. 2 in the diagram, shows some additional lines. In this case the jet was brass, and in this or some other way impurities may have been introduced; and I should, at present, incline to the view that the additional lines about λ 3429 and λ 3473, and the groups more refrangible than λ 3062, do not belong to the water spectrum, but to impurities.

Coal-gas was substituted for hydrogen in the oxyhydrogen blowpipe, and oxygen admitted in as large a proportion as possible. The inner blue flame rising about 2 inches above the jet showed in the visible part of the spectrum the usual "five-fingered spectrum." The

light from this part of the flame was projected upon the slit. The spectrum, No. 3 in the diagram, contains the water group already described, and in addition a very strong line close to G, and two lines, λ 3872 and λ 3890; this latter line is seen to be the more refrangible limit of a group of fine lines shading off towards K.

The ultra-violet group when carefully compared with the group in the spectrum of pure hydrogen, shows several small differences. I am inclined to believe that there is the superposition of a second fainter group. There is strong evidence of this in some spectra of hydrogen taken under other conditions. There is also a broad band less refrangible than the strong line at G, and the light extends from this line on its more refrangible side.

A double Bunsen burner (Fletcher's form) with a strong blast of air was then fitted up. The spectrum was taken of the intense blue flame. It resembles the one last described. All the distinctive features are intensified, and a continuous spectrum and groupings of very fine lines fill up all the intervals between the groups already described, so that there is an unbroken strong spectrum throughout the whole region which falls upon the plate.

A spirit lamp was arranged before the slit. The spectrum is essentially the same as No. 3, but as it is less intense only the strongest lines are seen. The water group, the strong line at G, and the pair of lines rather more refrangible than K, are seen. Probably with a longer exposure the finer lines would also show themselves.

The distinctive features of spectrum No. 3 appear to be connected with the presence of carbon.

Table of Wave-lengths of the Principal Lines of the Spectrum of Water. No. 1.

3062	3095	3135	3171	3217·5
3068	3099	3139	3175	3223
3073	3102	3142·5	3180	3228
3074	3105	3145	3184	3232
3077·5	3111	3149·5	3189	3242·5
3080	3117	3152·5	3192·5	3252·5
3082	3122·5	3156	3198	3256
3085	3127	3159·5	3201	3262
3090	3130	3163	3207·5	3266
3094	3133	3167	3211	3276

Wave-lengths of other Lines in Spectrum. No. 2.

2869·5	2910	2947	2991	3031
2872·5	2913	2951	2994	3039
2876	2917·5	2955	2999	3042
2880	2922·5	2959	3002	3046
2883	2925·5	2966	3005	3051
2887·5	2929	2967·5	3010	3057·5
2892	2932·5	2970·5	3013	3246
2895	2935·5	2975·5	3017	3271
2897	2940	2981	3019·5	3429·5
2904	2943	2989	3029	3473
2907·5				

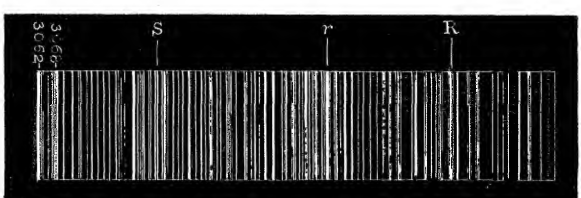
Wave-lengths of other Lines in Spectrum. No. 3.

3872	3890	4310

XV. "On the Spectrum of Water." By G. D. Liveing, M.A., F.R.S., Professor of Chemistry, and J. Dewar, M.A., F.R.S., Jacksonian Professor, University of Cambridge. Received June 17, 1880.

In our last communication to the Society, "On the Spectrum of the Compounds of Carbon with Hydrogen and Nitrogen, No. II," we noticed that a remarkable series of lines, extending over the region between the lines S and R of the solar spectrum, were developed in the flame of coal-gas burning in oxygen. The arrangement of lines and bands, of which this spectrum consists, is shown in the accompanying diagram,* fig. 1. It begins at the more refrangible end with two

Fig. 1.



strong bands, with wave-lengths about 3062, 3068, and extends up to about the wave-length 3210. It is well developed in the flame of hydro-

* This diagram gives tolerably well the general character of the spectrum, but the artist has not in all cases correctly rendered the relative strength of the lines. Those of the less refrangible half are almost too strongly rendered.

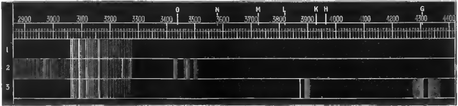

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Fig. 1.